# Tevatron End of Run Studies

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# Motivation and Plan

- Tevatron Accelerator Studies Workshop *(January 13-14, 2010)*
  - https://indico.fnal.gov/conferenceOtherViews.py?view=standard&confId=2921
  - Generated long list of studies to be considered, rough plans

- Fermilab AAC meeting *(July 28-30, 2010)*
  - https://indico.fnal.gov/conferenceDisplay.py?confId=3475
  - Strong support for an accelerator studies program

- DOE Institutional Review of Fermilab (June 6-9, 2011)
  - https://indico.fnal.gov/conferenceDisplay.py?confId=4263
  - Support of the proposed accelerator studies

- All Experimenters' Meeting (August 15, 2011)
  - http://www.fnal.gov/directorate/program_planning/all_experimenters_meetings/special_reports/Valishev_EOR_Studies_08_15_11.pdf

# List of Topics

1. AC Dipole with colliding beams
   - AC dipole is a device that adiabatically excites transverse oscillations of the beam. Turn-by-turn detection of oscillations at the excitation frequency allows to restore the beam optics.

2. Coherent Beam-Beam Modes
   - Colliding beams represent a system of coupled oscillators with their eigenfrequencies determined by beam and machine properties. Coherent instabilities may happen under certain conditions

3. Beam-Beam Resonances vs Separation
   - Study the importance of transverse beam-beam misalignment

4. Betatron Phase Averaging
   - Theory predicts that the magnitude of beam-beam effects is strongly affected by the ratio of transverse beta-function to the bunch length.

5. Diffusion Driven by Beam-Beam Resonances
   - Beam-beam effects interplay with other diffusion and noise sources

# Organization and Scheduling

- We have requested 40 hours of beam time over the two week period

- RunCo team calculated that 43 hours were used

  - Actual time with beam ~35 hours

- First week was strongly affected by the ecool troubles

- Nevertheless, achieved some good results!

# LHC Offset Beam-Beam Collision Studies (Ji Qiang)

- The offset collision is unavoidable due to the different bunch collision schemes at LHC
- Such offset collision might cause emittance growth that degrades luminosity lifetime and experimental conditions
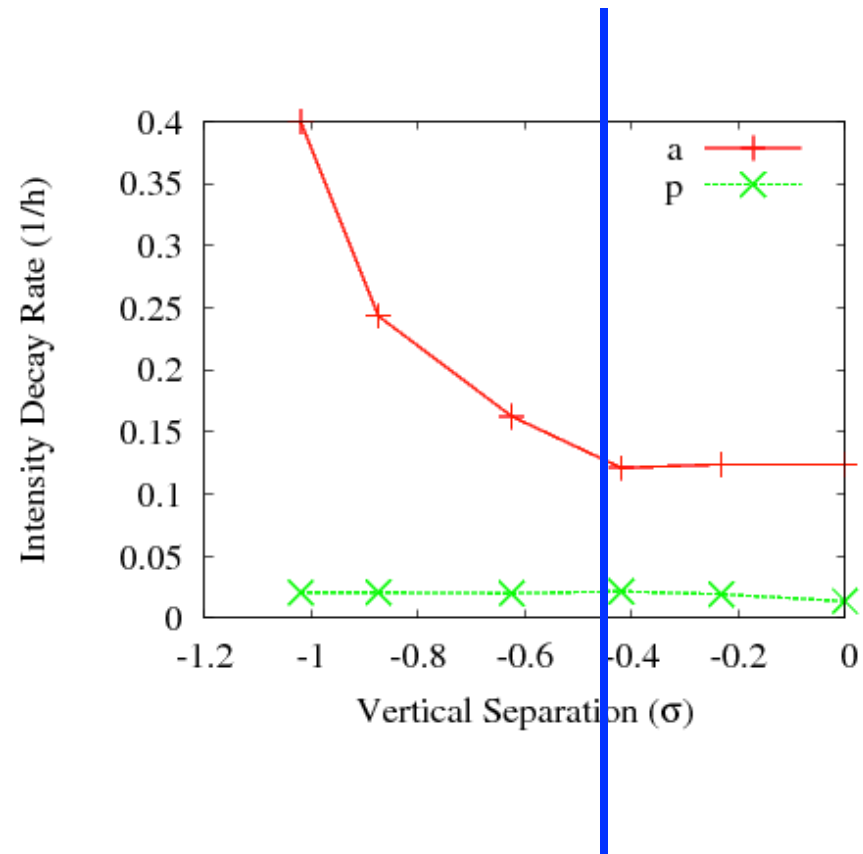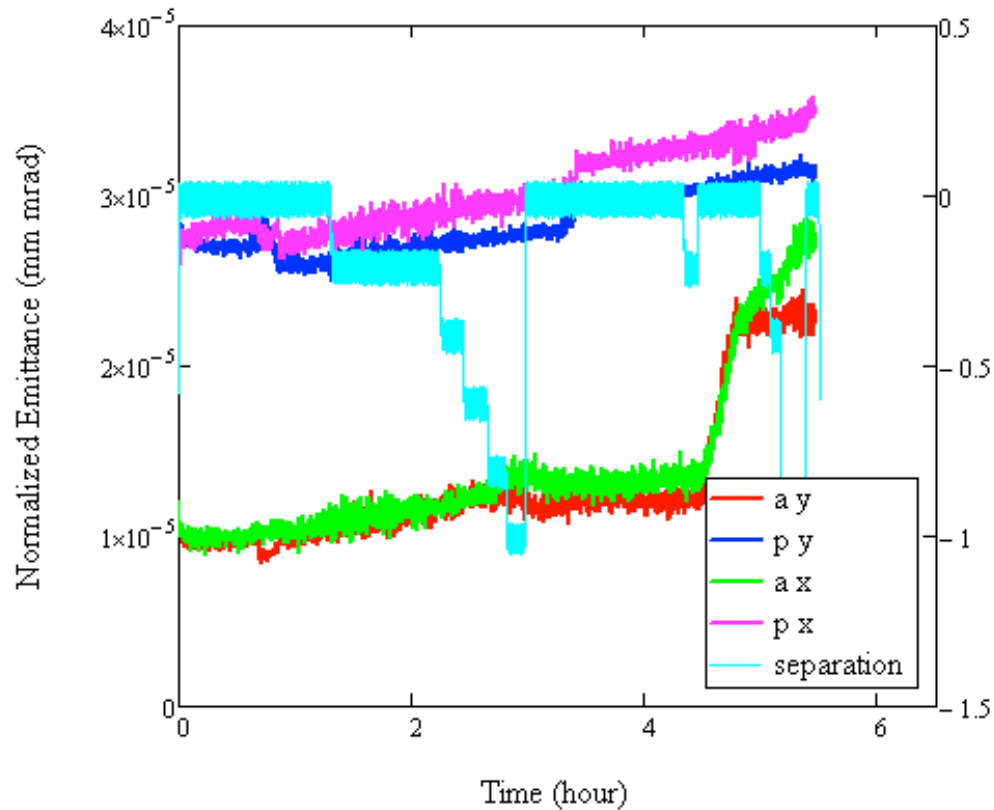
### Emittance Growth vs. Offset



emittance growth at the end 150k turns vs. initial vertical separation
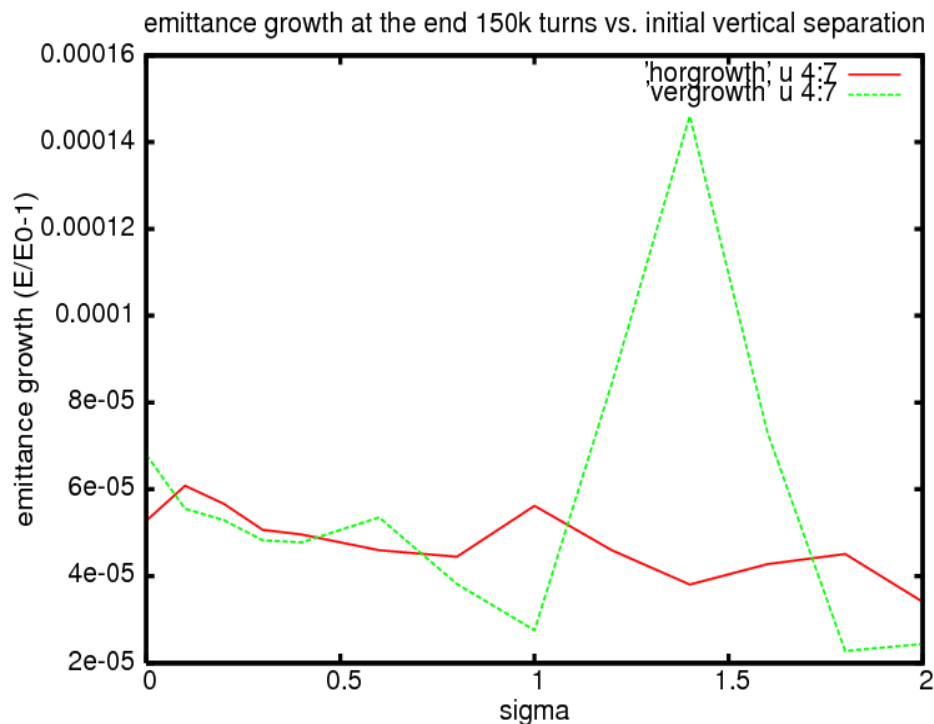
- We have made a systematic scan of the separation in the possible range which is consistent with the simulations

- There is no emit growth which would be consistent with the worst case being at ~1.5 sigma

# Separation Scan #1

# Coherent Beam-Beam

- Due to lack of high intensity & low emittance for the Pbars till about this Wednesday 24ᵗʰ we couldn't quite do that part (also the "driving force" Simon left on Sunday)
- However, "the other half", i.e. the chromaticity threshold study in conjunction of BB was very conclusive:
  - Whenever BB is present any chromaticity value can be dialed in without causing an instability! Some minor Schottky activity for Q' [0, ~-1]
  - This remains true independent of the chosen working point.
  - In case BB is weak but the emittance is large there is also no effect.
  - For a nominal 3x0 the instability was very fast slightly above 0, causing a quench – sorry!

# AC Dipole

- The goal was to excite the "weak" beam through the strong beam using the AC-dipole
- However, "without" excitation of the strong beam
- We need to record the turn-by-turn BPM data around the ring
- We had to reverse the weak-strong set-up since the BPM system operates in a turn-by-turn mode for protons only ➜ use lowest possible proton intensity against nominal low emittance pbars
- Changes to the linear lattice function due to BB can be derived from a reference measurement with protons only

- Successfully demonstrated the technique with colliding beams (3x3 bunches at LowBeta)! No instability or emittance growth after multiple excitations.
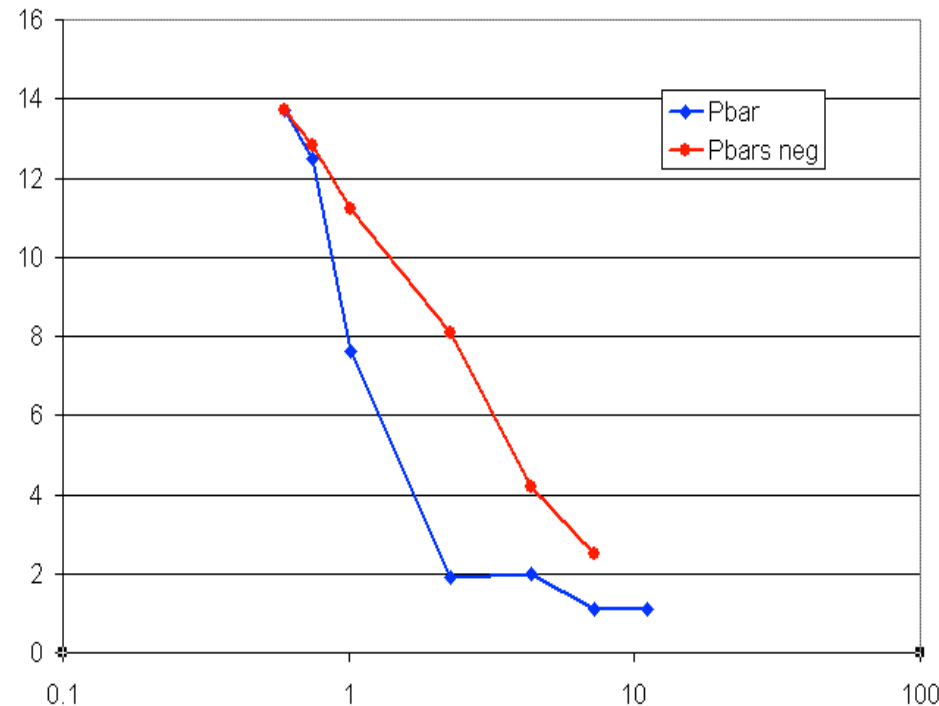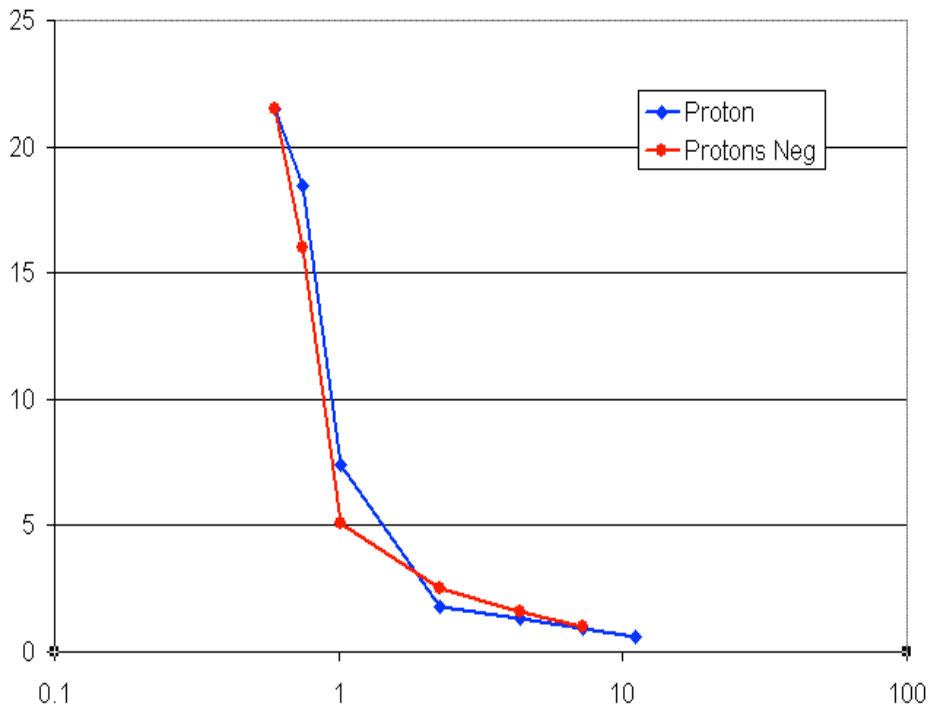
# AC Dipole
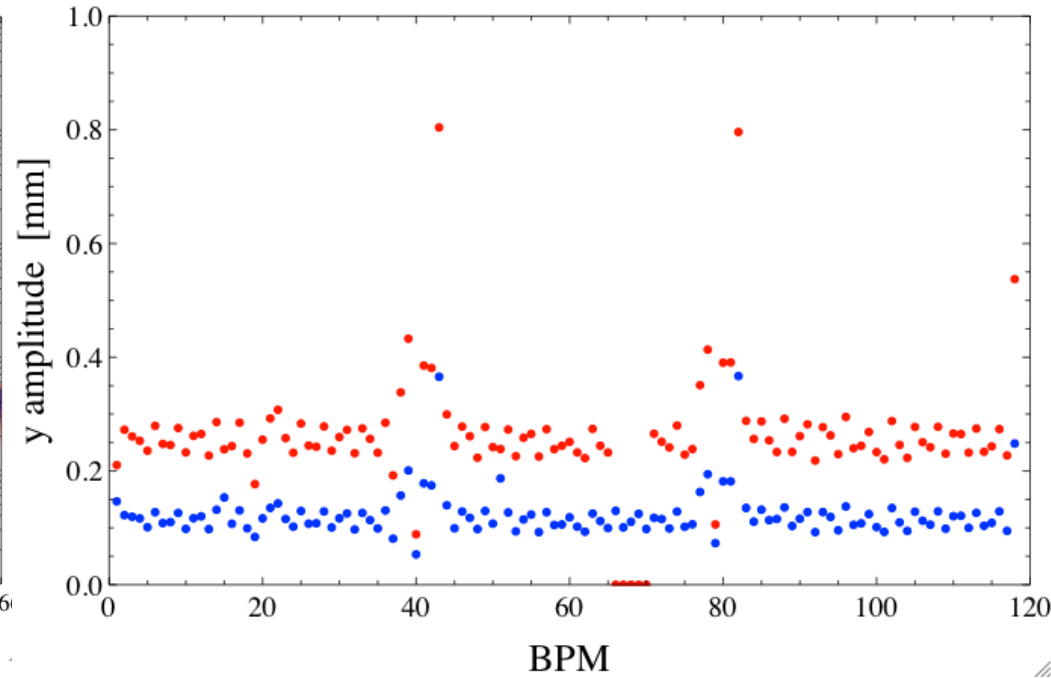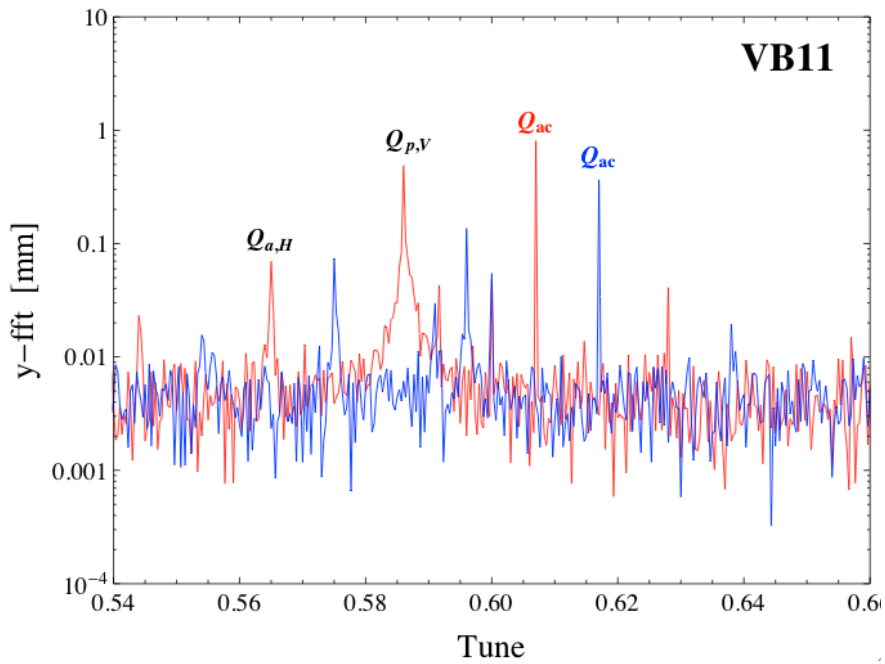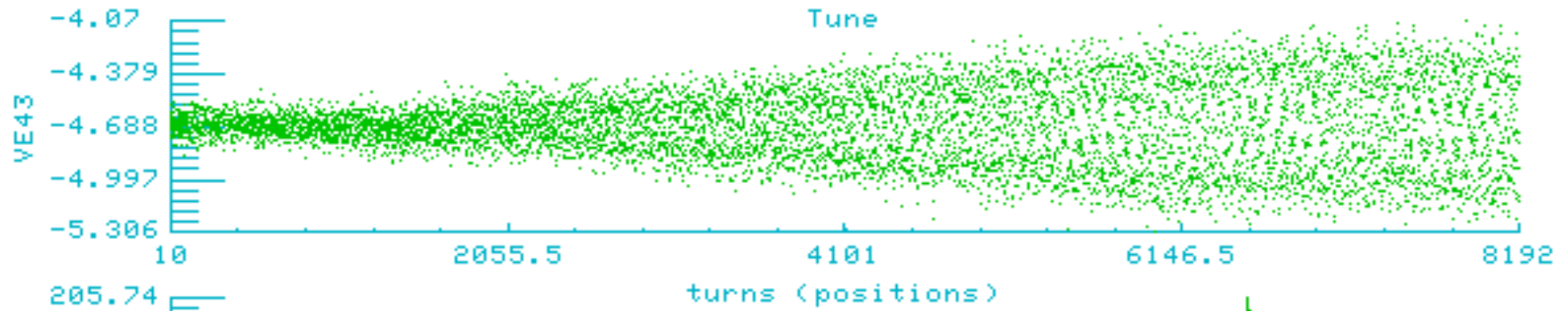
# Phase Averaging

- The goal was to collide bunches at different bunch length/beta* ratios
- This was achieved by cogging

- Produced excellent data, in qualitative agreement with expectations! Good for benchmarking future simulations.

proton (left) and pbar (right) lifetime vs beta*/sigma

# Summary

- Despite numerous technical issues and machine failures, the studies were successful in many aspects:
    1. Proof-of-principle experiment with AC dipole acting on colliding bunches
    2. Demonstration of the Landau damping of coherent instability by beam-beam interaction
    3. Measurement of the "phase averaging effect" – lifetime vs. bunch length / beta*
    4. Measurement of the effect of transverse beam-beam separation on intensity and emittance
- Many thanks to the experiments for donating time
- We are indebted to the Run Coordinators and Operations personnel for making these studies happen
- A technical note summarizing the results will be published soon

A.Valishev, All Experimenters Meeting